Cover crops as a tool to reduce reliance on intensive tillage and nitrogen fertilization in conventional arable cropping systems

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Supplement

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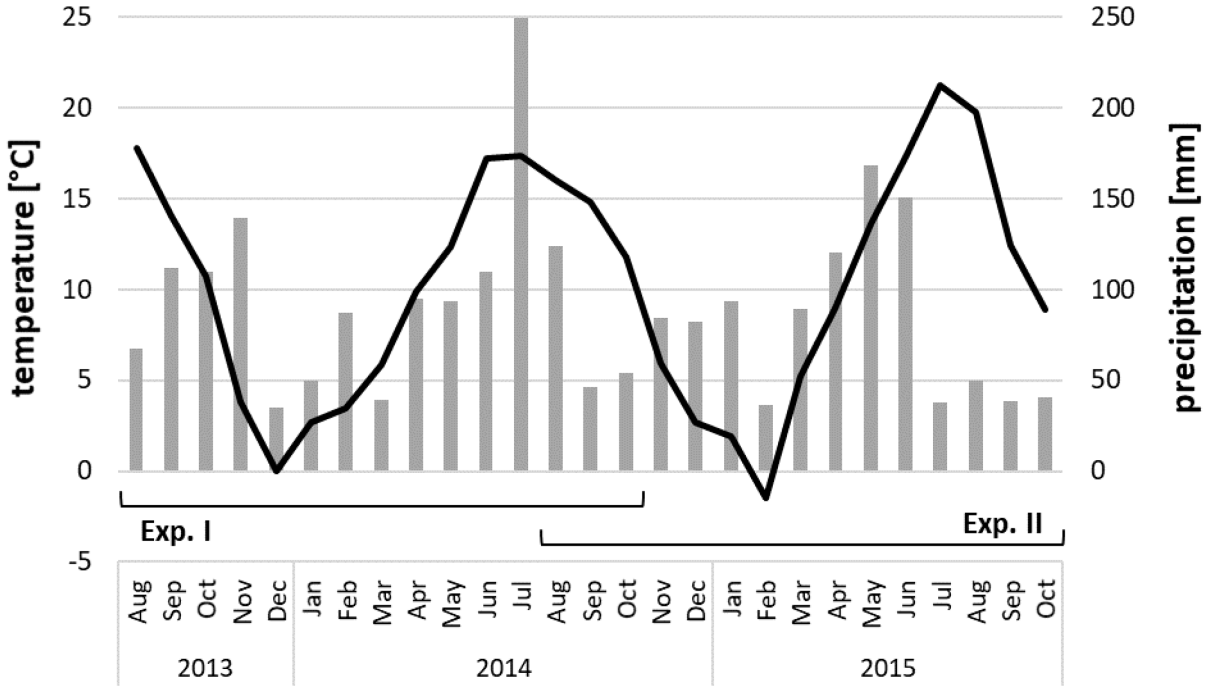
Supplementary Table S1: Summary of crop management and field operations in experiment 1 (Exp. I) and experiment 2 (Exp. II). IT: intensive tillage, NT: no tillage, RT: reduced tillage / C: no cover crop, RS: oilseed radish, TS: subterranean clover, VV: hairy vetch / 100N: full fertilization, 50N: half fertilization.

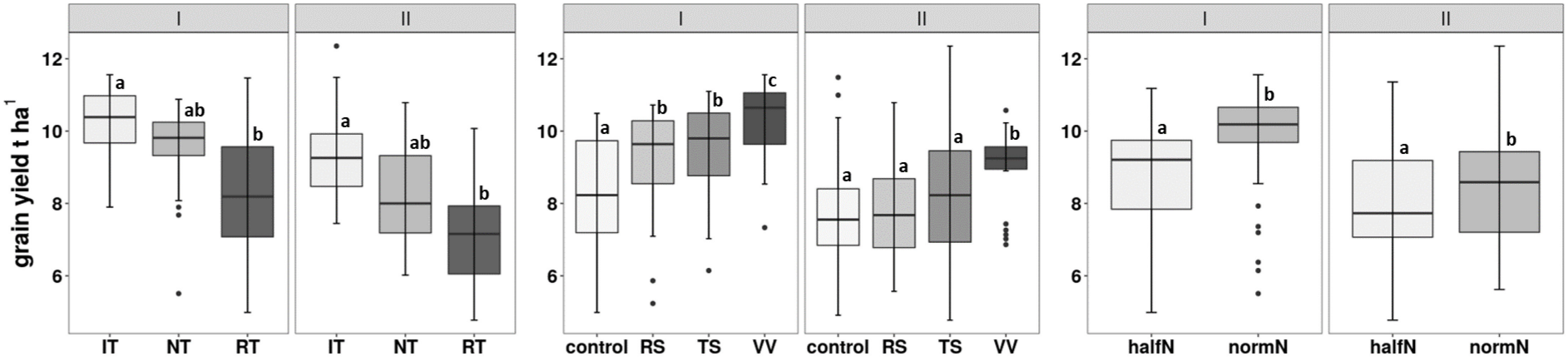
Field operations	Exp. I	Exp. II	Treatments	Amount / Product / Device
Winter wheat				
Winter wheat sowing Winter wheat + TS sowing	05.10.2012	03.10.2013	All	**C, RS, VV**: 190 kg ha^{-1} **TS**: 170 kg ha^{-1} + 19 kg ha^{-1} TS
1. N fertilization (NH_4 - NO_3)	03.04.2013	19.03.2014	All	**100N**: 70 kg N ha^{-1} **50N**: 45 kg N ha^{-1}
Herbicide application	25.04.2013	04.04.2014	**all except TS**	1.1 l Archipel + 1.0 l Starrane180
2. N fertilization (NH_4 - NO_3)	25.04.2013	17.04.2014	All	**100N**: 30 kg N ha^{-1} **50N**: 25 kg N ha^{-1}
3. N fertilization (NH_4 - NO_3)	11.06.2013	26.05.2014	**100N**	**100N**: 40 kg N ha^{-1}
Harvest wheat grain	03.08.2013	25.07.2014	All	
Straw removal	15.08.2013	06.08.2014	All	
Cover crops				
Stubble cultivation (5 cm)	21.08.2013	06.08.2014	All	Rotary cultivator
Cover crop sowing	21.08.2013	07.08.2014	All	**RS**: 25 kg ha^{-1} **TS**: 19 kg ha^{-1} **VV**: 100 kg ha^{-1}
Maize				
Glyphosate	30.04.2014	29.04.2015	**NT**	4 l Glyphosat 360S
Cover crop mulching	18.05.2014	13.05.2015	**IT, RT**	
Moldboard plough (20 cm)	19.05.2014	13.05.2015	**IT**	
Precision cultivator (2-3 cm)	21.05.2014	18.05.2015	**RT**	Weco-dyn, Wenz GmbH
Precision cultivator (5-6 cm)	21.05.2014	28.05.2015	**RT**	Weco-dyn, Wenz GmbH
Seedbed preparation (5 cm)	21.05.2014	28.05.2015	**IT**	Rotary harrow
Maize sowing	22.05.2014	28.05.2015	All	kg ha^{-1}
1. N fertilization (underfoot)	22.05.2014	28.05.2015	All	**100N**: 30 kg N ha^{-1} **50N**: 30 kg N ha^{-1}
Herbicide application	21.06.2014	29.06.2015	**IT, NT**	Exp.I: 1.5 l Calaris + 1.0 l Nicogan + 1.2 l Dual Gold Exp.II: 1.5 l Calaris + 0.9 l Nicogan + 0.2 l Banvel4S
1. hoeing	23.06.2014	29.06.2015	**RT**	Star cultivator
2. N fertilization (NH_4 - NO_3)	03.07 2014	30.06.2015	all	**100N**: 60 kg N ha^{-1} **50N**: 15 kg N ha^{-1}
2. hoeing		09.07.2015	**RT**	Star cultivator
Harvest biomass	09.10.2014	08.10.2015	all	
Harvest grain	30.10.2014	28.10.2015	all	

Supplementary Table S2: Weed cover and biomass and Cover crop cover, biomass under the different cover crop treatments. The percentage of cover was assessed at 60 days after sowing (DAS), and the total biomass produced, nutrient content, and nitrogen derived from atmosphere (Ndfa) was measured in the spring directly prior to tillage operations. The values given are the mean ± ci, different letters indicates significant differences between cover crop treatments (Tukey test, $p<0.05$).

	Weed		Cover crop				
	cover	biomass	cover	biomass	N content	C/N ratio	Ndfa
	% at 60 DAS	[kg ha^{-1}]	% at 60 DAS	[kg ha^{-1}]	[kg N ha^{-1}]		[kg N ha^{-1}]
control	53 ± 3.6 a	417 ± 56 a	-	-	-	-	-
radish (RS)	6 ± 1.9 c	93 ± 24 c	65 ± 5.3 a	482 ± 91 a	8 ± 1.7 a	30 ± 3.0 a	-
subclover (TS)	15 ± 3.9 b	295 ± 50 b	74 ± 6.0 a	1075 ± 172 b	32 ± 5.4 b	15 ± 0.5 b	19 ± 3.3 a
hairy vetch (VV)	4 ± 0.9 c	50 ± 12 c	96 ± 1.0 b	3312 ± 263 c	142 ± 11.6 c	10 ± 0.2 c	125 ± 10 b

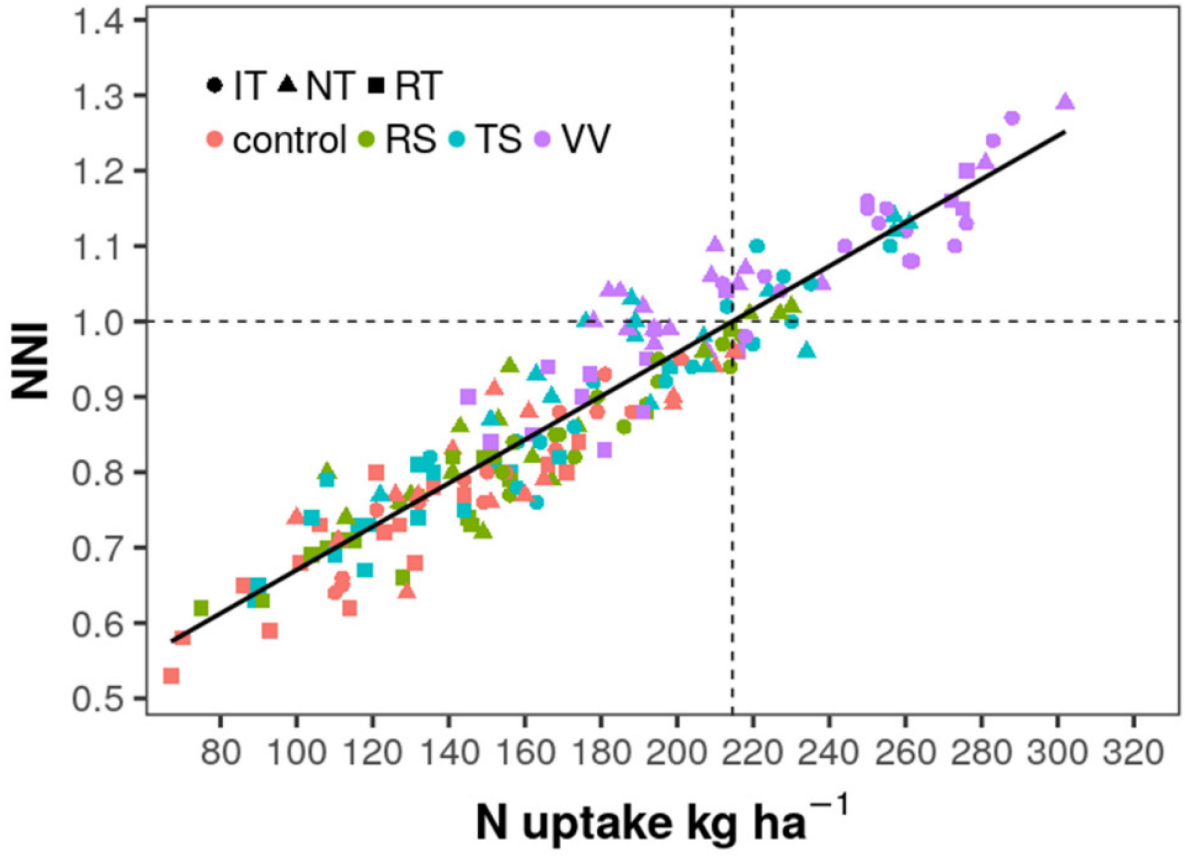


Supplementary Figure S1: Mean temperature and sum of precipitations of the growing seasons of cover crops and maize for Experiment I and II.



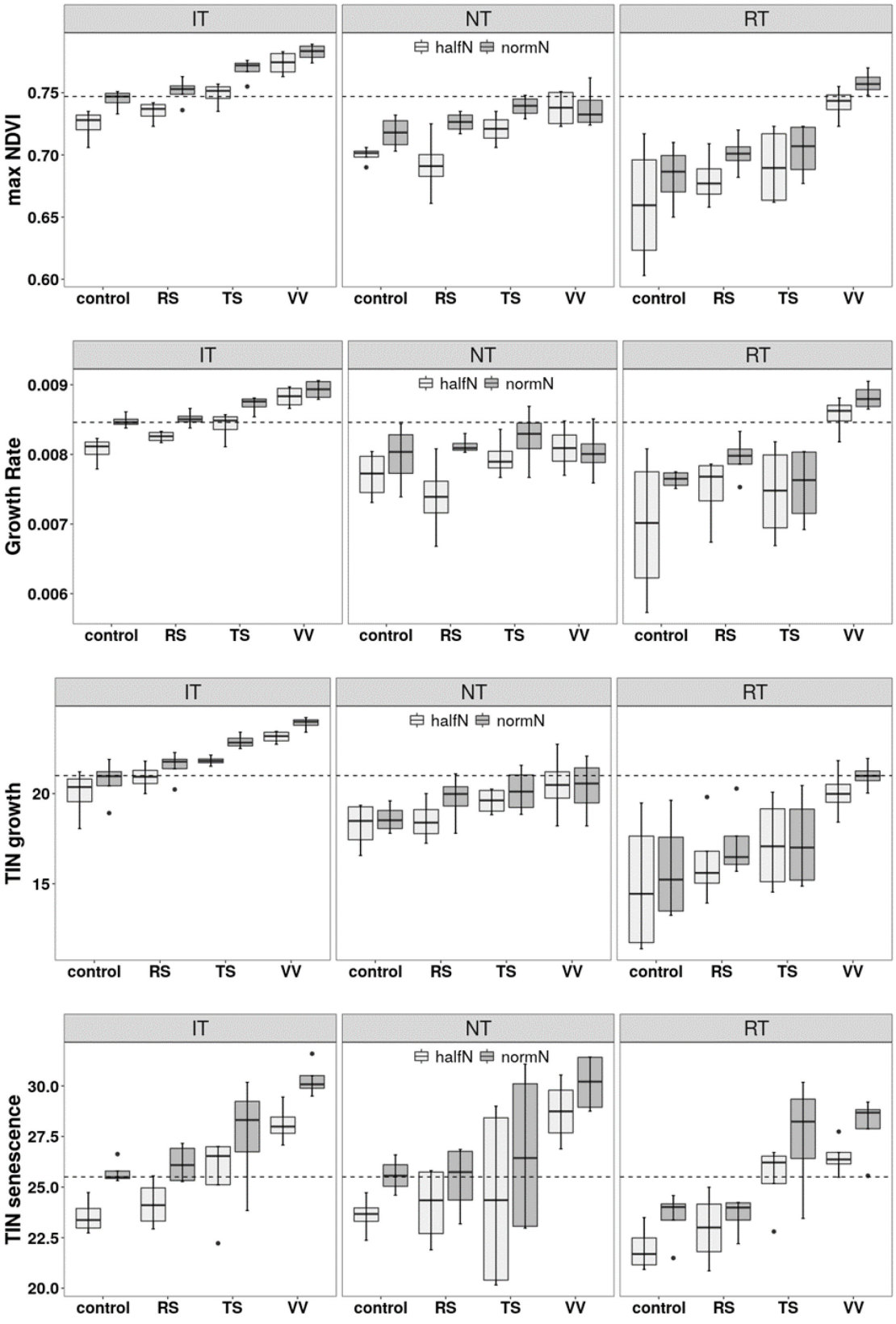
Supplementary Figure S2: Maize grain yield for the main factors within each experiment I and II (year). Different letters indicate significant differences between treatments within one experiment (Tukey test, $p<0.05$). Only the interaction between experiment and fertilization is significant. For statistical details see Table 1 in the original article.

IT: intensive tillage, NT: no tillage, RT: reduced tillage / control: no cover crop, RS: oilseed radish, TS: subterranean clover, VV: hairy vetch / normN: norm fertilization, halfN: half fertilization.

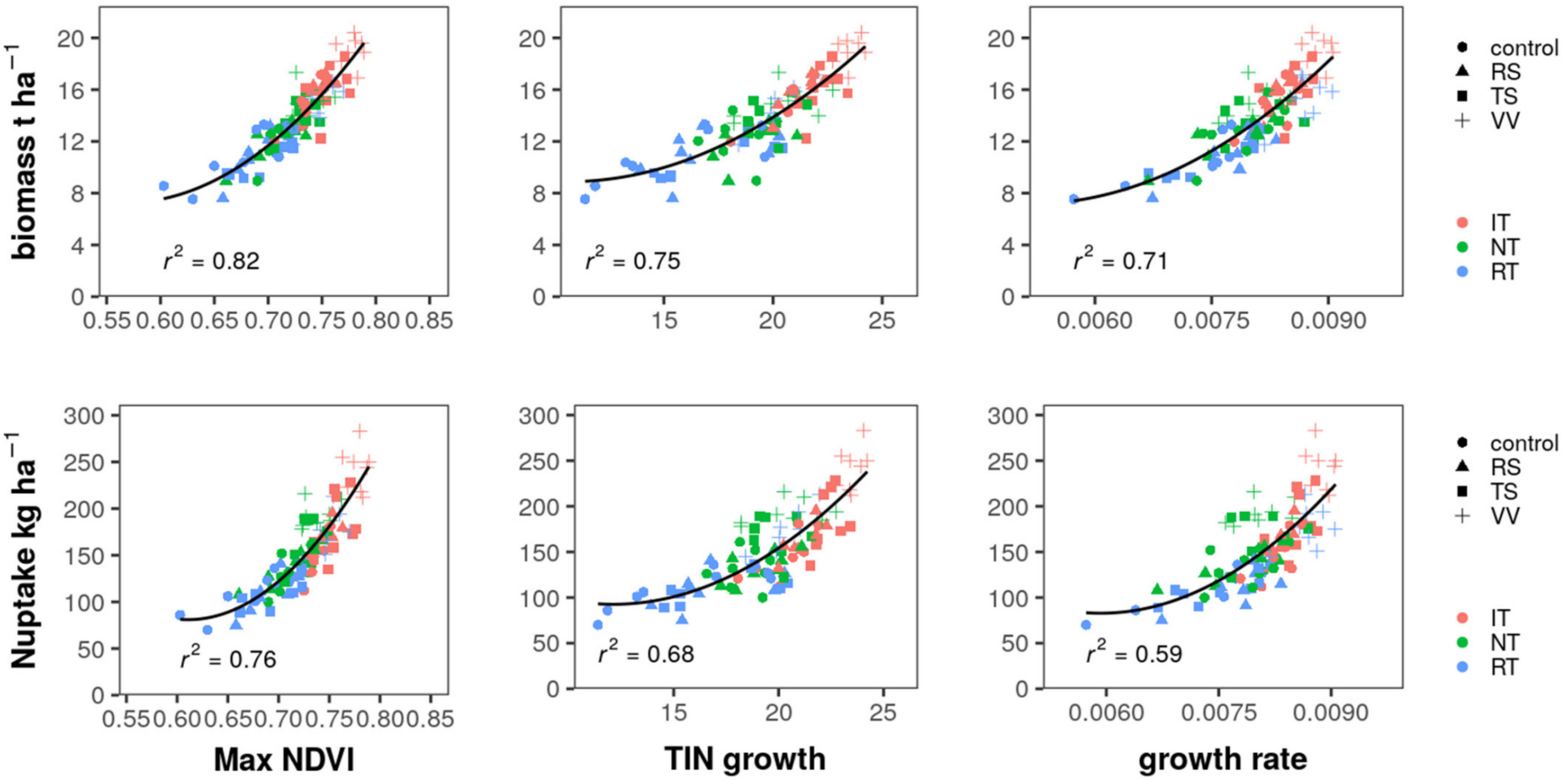


Supplementary Figure S3: Relationship between maize N uptake and the N nutrition index (NNI). An NNI above 1 indicates no N limitation for the crop.

IT: intensive tillage, NT: no tillage, RT: reduced tillage / control: no cover crop, RS: oilseed radish, TS: subterranean clover, VV: hairy vetch



Supplementary Figure S4: Maize growth phenological parameters (n=4) in four cover crop treatments (control; oilseed radish (RS); subterranean clover (TS); hairy vetch (VV)) under intensive tillage (IT), no tillage (NT) and reduced tillage (RT) and norm and half fertilization. The dashed lines represent the mean value of the reference treatment with intensive tillage, norm fertilization and no cover crop.



Supplementary Figure S5: Correlation (polynomial regressions second order) between crop growth parameters calculated from UAV imagery and maize biomass and N uptake (Max NDVI: maximal NDVI value, TINgrowth: Time Integrated NDVI until 76 days after sowing (half growing period)). (IT: intensive tillage, NT: no tillage, RT: reduced tillage) (control: no cover crop, RS: oilseed radish, TS: subterranean clover, VV: hairy vetch).